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Research Article

Location Decision-Making of Equipment Manufacturing Enterprise under Dual-Channel Purchase and Sale Mode

Wei Xu, Lina Liu, Qingshan Zhang, and Peng Liu

School of Management, Shenyang University of Technology, Shenyang 110870, China

Correspondence should be addressed to Lina Liu; 1296855532@qq.com

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Based on the current status of the development of equipment manufacturing enterprises, the main influencing factors and main evaluation indicators of the equipment manufacturing enterprises in the context of dual-channel marketing are analyzed and determined. According to the organizational layout and transaction form of equipment manufacturing enterprises, the problem of equipment manufacturing enterprise location decision-making with online channel and offline channel trading mode is divided into two categories. One is the single-plant location decision problem, and the other is the multiplant location decision problem. In the single-plant location decision problem, we have established the conceptual model and mathematical model. Based on prospect theory, we use multicriteria decision-making method to quantify and standardize the evaluation index and determine the reference value, and the priority of the scheme is determined according to the final comprehensive value. In the multiplant location decision problem, we have established the conceptual model and the logical model and established the mathematical model with the goal of minimizing the cost and time. Finally, an example is given to solve the location problem of single plant and multiple plants. The feasibility of the model is proved by the solution and verification.

1. Introduction

The rapid change of information technology promotes the intelligent development of manufacturing industry. For example, the United States proposes the "Industrial Internet", the EU plans to build "Future Factory", Germany is leading revolution "Industry 4.0", and China plans for "Made in China 2025". In the past decade, China's manufacturing industry has made remarkable progress in high-speed railways, construction equipment, communications, and drones. At the same time, it has made a leading position in the global market. As the main force for national industrial development and the development of economy, technology, and national defense, equipment manufacturing is the foundation for the country to become stronger. At present, the marketing concept has changed from "market-centered" to "customer-centered". Equipment manufacturing enterprises must be transformed and upgraded in time to meet the diversified demand of customers. In addition to the appearance, configuration, and other aspects of the product, the diversified demands of customers also have different requirements for service quality, such as product delivery methods and delivery time. For equipment manufacturing enterprises, the online and offline purchasing and sales models will become a new trading channel because of its accurate and convenient characteristics, so as to meet the needs of the customer's personalized transaction. Therefore, considering the difference between the dual-channel trading mode and the traditional transaction model, we put forward the problem of the location decision of the equipment manufacturing enterprise with dual-channel purchase and marketing. The purpose is to make the enterprise better configure the resources to meet and satisfy the new needs of the customers, and to ensure that the customers in each area can receive the products on time and completely.

2. Literature Review

The problem and theory of location decision originated from 1909. After more than 100 years of research and excavation by many scholars, now the location theory can be divided into the classical location theory such as the covering location theory [1], the center location theory [2], and the medium location theory [3]. The research on location has also gradually extended to the progressive coverage location problem [4], standby coverage location problem [5], stratified facilities location problem [6], and competitive location problem [7]. Scholars proposed specific solutions to different location problems, expanded the scope of application of the site selection theory, and guided practical problems, such as the location of factories, warehouses, and logistics distribution centers and the location of public facilities, hospitals, and emergency service stations. At present, the location theory has gradually matured, but scholars' enthusiasm for location problem has not diminished. In particular, the current world structure is changing with each passing day, and the factors of production are more and more inclined to free flow in a wide range. With the gradual development of industrial 4, cloud services, and intelligent manufacturing, other advanced industrial revolutions have begun. Online and offline channels of mutual integration of trading mode gradually began to be adopted by many equipment manufacturing enterprises.

In this paper, we combine the prospect theory with location theory to study the location decision-making of manufacturers with dual-channel procurement and sales. The prospect theory, which was proposed by Kahneman and Tversky in 1979, describes the risk decision-making behavior of people in two different situations, namely, "gain" and "lost" [8]. Unlike traditional expectation theory and expected utility theory, prospect theory is a multiple-attribute decision-making theory that incorporates psychology. It can better describe people's decision-making behavior. Kahneman won the Nobel Prize in economics in 2002 for his theory of prospect. At present, prospect theory is used to solve all kinds of decision-making problems. Ding Q L. et al. [9] studied the interference management model of the logistics distribution system under the uncertain events, such as delivery address, customer time window, or demand, and determined the method of disturbance measurement based on the prospect theory. Gao S. et al. [10] applies the prospect theory to the decision-making of the power grid planning scheme. By constructing the index system, the value function, and the weight function, the comprehensive prospect value of each scheme is determined and the optimal scheme is selected. Considering the participation of competing products, Jiang Y P. et al. [11] decided to develop new product development plan based on prospect theory. And Chu H R. et. al. [12] studied the newsvendor model under three conditions: buyback contract, shortage penalty, and repurchase and penalty. Gao J W. et. al. [13] combined the prospect theory with interval valued intuitionistic fuzzy numbers and designed an interval valued intuitionistic fuzzy multiple criteria decision-making method based on prospect theory. Qinghe Chen et. al. [14] established the location decision model, according to the characteristics of the old-age health club, combined with the maximum coverage requirements of public facilities. And the satisfaction function was determined by using the foreground theory. Finally, they give an example and get a satisfactory solution through genetic algorithm. That paper is based on the satisfaction of the elderly, with the goal of unilateral satisfaction of one subject. We considered location decision-making on the view of suppliers, producers, online consumers, and offline consumers; there are four participants as decision-makers to get satisfaction. The location decision of the elderly health club is only considered about the cost of facility establishment, which is a static decision. In this paper, transportation costs of both suppliers and distributors are included, which is a dynamic decision.

3. Problems Description

3.1. Conceptual Model. The location of the factory is an important long-term decision. It not only directly determines the construction cost of the company, but also affects the expenses incurred in the future production and operation of the company, as well as the market development. And, once the decision is determined, it is difficult to change. There are two main issues that need to be resolved in the problem of factory location. The first is selection, which is to choose an area to build the factory. The second is addressing. That is, after selecting a region, specifically choose where to build a factory in the region. When making specific decisions, it is necessary to actually consider three kinds of situations, including the location of a new plant, the relocation of the original site, and the addition of several factories to expand production on the basis of the existing plant. In this paper, we assume that the entity logistics through the online exchange is a third-party logistics carrier. Businesses procure raw materials and sell customer order products through the cloud or website. The two parties implement the payment process through the Internet platform and determine the related responsibilities such as returning goods for replacement. The location of the plant is determined based on the company's development status, expected goals, the degree of development of the dual-channel marketing model, and the location and purchase or sales volume of the identified and estimated suppliers and demand points. According to the organizational layout and transaction forms of the existing factories, the concept models for single-plant site selection and multiplant site selection were established, as shown in Figures 1 and 2.

3.2. Model Parameters. Symbolic definition and parameter description:

S: $S = \{S_i \mid i = 1, 2, \cdots, l\}$: A set of l suppliers, where S_i is the i-th supplier.

P: $P = \{P_j \mid j = 1, 2, \cdots, m\}$: A set of m alternative plants, where P_j is the j-th alternative point.

G: $G = \{G_k \mid k = 1, 2, \cdots, n\}$: A set of n demand points, where G_k is the k-th demand point.

C_{Pr}: Production costs. $C_{\mathrm{Pr}}(i)$ is the production cost of the i-th plant. It is related to the production scale of the factory.

U: $U = \{U_j \mid j = 1, 2, \cdots, m\}$: A set of production scales of m plants, where U_j is the production scale of the j-th plant.

C_{Tr}: Transportation cost. It includes procurement transportation costs and sales transportation costs. Transportation costs are related to shipping rates and distances.

C_{Rt}: Return cost. It includes returns losses that occur during the purchase and sale process. The return cost is related to the return rate.

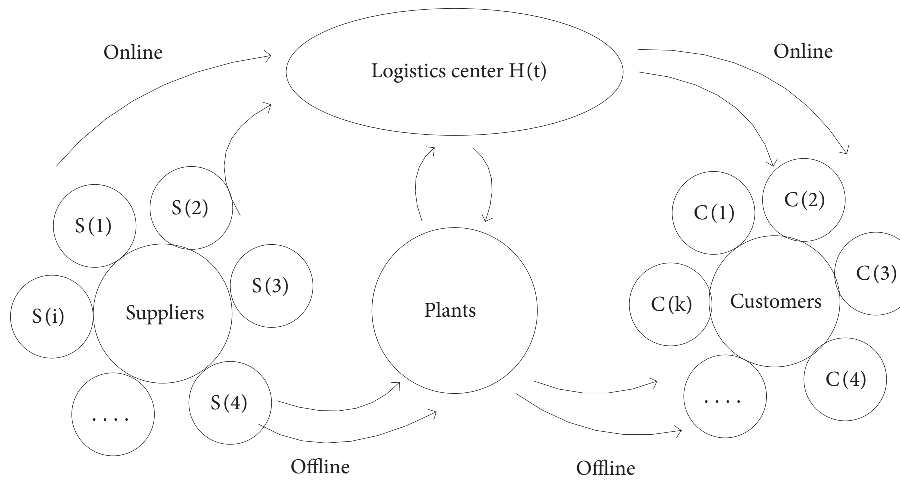

FIGURE 1: Conceptual model of single-plant location.

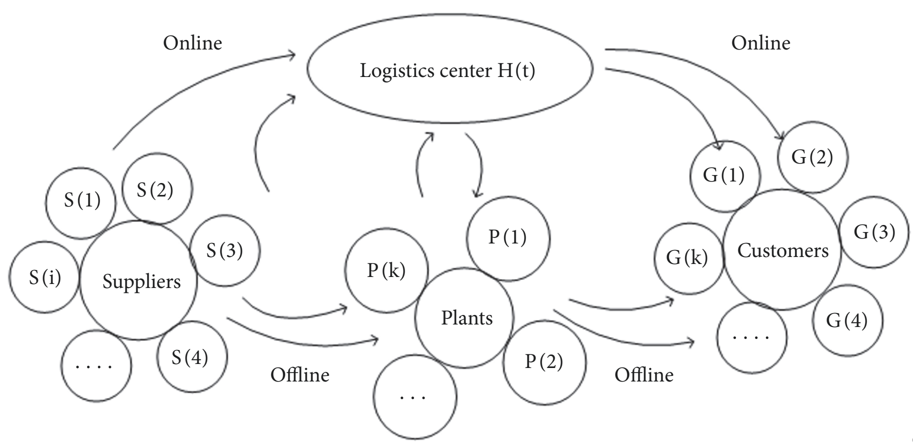

FIGURE 2: Conceptual model of multiplant location.

C: Total cost. It includes production costs, transportation costs, and return costs.

Q_{ij}: The amount of raw material provided by supplier S_i to plant P_j.

Q_{jk}: The amount of products provided by plant P_j to demand point G_k.

d_{ij}: The distance between supplier S_i and plant P_j.

d_{jk}: The distance between P_j and demand point G_k.

D_j^1: The maximum coverage radius for the j-th factory offline service.

D_j^2: The maximum coverage radius for the j-th factory online service. The service interval for online transactions is $[D_j^1, D_j^2]$.

w: Freight rate. $\{w_1^{off}, w_2^{off}, w_1^{on}, w_2^{on}\}$, respectively, represent the freight rates for online purchase, online sale, offline purchase, and offline sale.

y: Return probability (return rate). $\{y_1^{off}, y_2^{off}, y_1^{on}, y_2^{on}\}$, respectively, represent the return probability for online purchase, online sale, offline purchase, and offline sale.

τ: Transportation time per unit distance. $\{\tau_1^{off}, \tau_2^{off}, \tau_1^{on}, \tau_2^{on}\}$, respectively, represent the transportation time per unit distance for online purchase, online sale, offline purchase, and offline sale.

ζ: Unit return cost. $\{\zeta_1^{off}, \zeta_2^{off}, \zeta_1^{on}, \zeta_2^{on}\}$, respectively, represent the unit return cost for online purchase, online sale, offline purchase, and offline sale.

z: Maximum number of factories.

$\overset{*}{F}$: $\overset{*}{F} = \{\overset{*}{F}_i \mid i = 1, 2, \cdots, n\}$: A set of n first-level attributes. F_i is the i-th attributes, where $F_1, F_2, \cdots, F_n$ are independent of each other. We set $\overset{*}{F}_1 = \{C_1, C_2, \cdots, C_{n1}\}$, $\overset{*}{F}_2 = \{A_1, A_2, \cdots, A_{n2}\}$, $\overset{*}{F}_3 = \{T_1, T_2, \cdots, T_{n3}\}$, $\overset{*}{F}_4 = \{Q_1, Q_2, \cdots, Q_{n4}\}$, $\overset{*}{F}_5 = \{B_1, B_2, \cdots, B_{n5}\}$.

F: A set of second-level attributes to F, $F = \overset{*}{F}_1 \cup \overset{*}{F}_2 \cup \overset{*}{F}_3 \cup \overset{*}{F}_4 \cup \overset{*}{F}_5 = \{F_\gamma \mid \gamma = 1, 2, \cdots, k\}$. Let $F_{j\gamma}$ be the value of the γ-th attribute about the j-th alternative, and $F' = \{F_{j\gamma} \mid j = 1, 2, \cdots, m; \gamma = 1, 2, \cdots, k\}$.

$\overset{*}{W}$: $\overset{*}{W} = \{\overset{*}{W}_i \mid i = 1, 2, \cdots, n\}$: A set of the weight vectors of n first-level attributes, among which, $\overset{*}{W}_i$ is the weight of i-th first-level attribute. It satisfies $\overset{*}{W}_i \geq 0$, $\sum_{i=1}^{n} \overset{*}{W}_i = 1$. $\overset{*}{W}_1 = \{\overset{*}{W}{}_C^1, \overset{*}{W}{}_C^2, \cdots, \overset{*}{W}{}_C^{n1}\}$ is a set the weight vectors of $\{C_1, C_2, \cdots, C_{n1}\}$. The weights of $\{A_1, A_2, \cdots, A_{n2}\}$, $\{T_1, T_2, \cdots, T_{n3}\}$, $\{Q_1, Q_2, \cdots, Q_{n4}\}$, $\{B_1, B_2, \cdots, B_{n5}\}$ are

$$\begin{gathered}\overset{*}{W}_2 = \left\{\overset{*}{W}{}_T^1, \overset{*}{W}{}_T^2, \cdots, \overset{*}{W}{}_T^{n3}\right\}, \\ \overset{*}{W}_3 = \left\{\overset{*}{W}{}_A^1, \overset{*}{W}{}_A^2, \cdots, \overset{*}{W}{}_A^{n2}\right\}, \\ \overset{*}{W}_4 = \left\{\overset{*}{W}{}_Q^1, \overset{*}{W}{}_Q^2, \cdots, \overset{*}{W}{}_Q^{n4}\right\}, \\ \text{and } \sum_{i=1}^{n1} \overset{*}{W}{}_C^i = 1, \\ \sum_{i=1}^{n2} \overset{*}{W}{}_T^i = 1, \\ \sum_{i=1}^{n3} \overset{*}{W}{}_A^i = 1, \\ \sum_{i=1}^{n4} \overset{*}{W}{}_Q^i = 1, \\ \sum_{i=1}^{n5} \overset{*}{W}{}_B^i = 1.\end{gathered} \tag{1}$$

W: $W = \overset{*}{W}_C \cup \overset{*}{W}_T \cup \overset{*}{W}_A \cup \overset{*}{W}_Q \cup \overset{*}{W}_B = \{w_\gamma \mid \gamma = 1, 2, \cdots, k\}$: A set of weights of k second-level attributes.

At the same time, define the decision variables as follows.

$$\begin{gathered}x_j : \begin{cases} x_j = 1, & \textit{alternative points are selected} \\ x_j = 0, & \textit{alternative points are not selected} \end{cases} \\ a_{ij} : \begin{cases} a_{ij} = 1, & 0 \leq d_{ij} \leq D_j^1 \\ a_{ij} = 0, & \textit{or else} \end{cases} \\ b_{ij} : \begin{cases} b_{ij} = 1, & D_j^1 \leq d_{ij} \leq D_j^2 \\ b_{ij} = 0, & \textit{or else} \end{cases}\end{gathered} \tag{2}$$

4. The Decision-Making Model of Single-Plant Location

4.1. Determining the Evaluation Index. According to the characteristics of procurement, production, transportation, and sales of equipment manufacturing enterprises, the traditional operating model of equipment manufacturing enterprises is integrated with the Internet.

In this context, based on the consensus of the previous literature research and the actual investigation of the manufacturers, we classified the factors affecting the location of equipment manufacturing enterprises as five types of influencing factors. In accordance with these five dimensions, 13 appraisal indicators with good applicability were determined, and the hierarchical structure model of the decision-making factors of equipment manufacturing enterprises was constructed, as shown in Figure 3.

(1) Cost Factors. The main considerations are construction costs, knowledge costs, and production and operation costs. The construction cost includes land cost and construction cost; the knowledge cost includes network cost and information cost; and the production and operation cost mainly includes transportation expenses and warehousing expenses incurred during the production and operation process.

(2) Time Factor. It mainly considers the transportation time of raw materials and the delivery time of products in the dual-channel procurement and sales process to ensure timely arrival of raw materials and timely delivery of products.

(3) Regional Condition Factors. It mainly examines the geographical conditions, industrial conditions, and logistics conditions of the alternative areas. The geographical conditions mainly include road conditions and distances from airports and ports; the industrial conditions mainly examine whether the surrounding industrial environment is agglomeration and how the competition is; and the logistics conditions mainly include the degree of perfection of the logistics industry and whether it can be competent for the product distribution tasks of the manufacturers.

(4) Quality of Service Factors. It mainly considers the quality of the rapid feedback of the manufacturers to the supplier in the alternative area and the quality of the rapid response to the customer.

(5) External Environmental Factors. It mainly examines whether the regional policy conditions in the candidate areas are superior, whether the information environment is perfect and popular, and whether it destroys the natural environment and does not comply with green manufacturing.

4.2. Modeling

4.2.1. Prospect Theory. Prospect theory is a theory describing and predicting the behavior that people are inconsistent with traditional expectation theory and expected utility theory in the process of facing risk decision-making. It is found that the risk preference behavior of people in the face of gains and losses is inconsistent. It becomes a risk pursuit in the face of "loss"; while facing "gain", the risk evasion can be avoided. The establishment and change of reference points affect people's gain and loss feelings and then influence people's decision-making. Figure 4 is a value function diagram.

According to this value function, people show loss aversion; that is to say, people are more sensitive to losses than to gain. Kahneman and Tversky did such an experiment. They gave the participants a chance to flip a coin: Once the coin was turned up, the subject got 20 dollars, and if they face it up, the subject lost 10 dollars. Because of people's loss aversion, most of the participants refused to participate in this game, even if

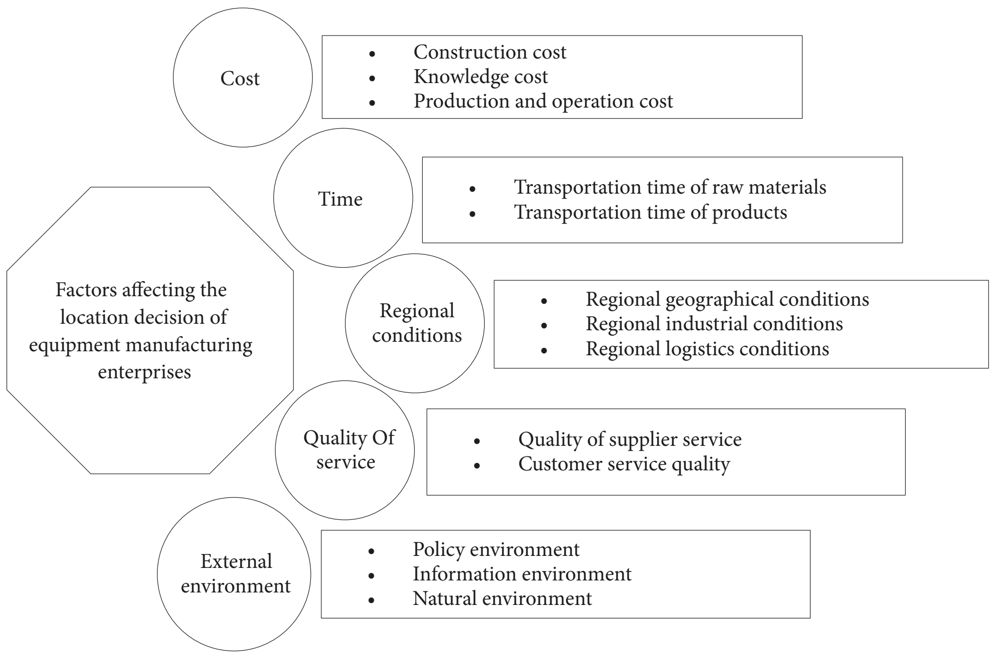

Figure 3: The structural model of the location decision-making influencing factors.

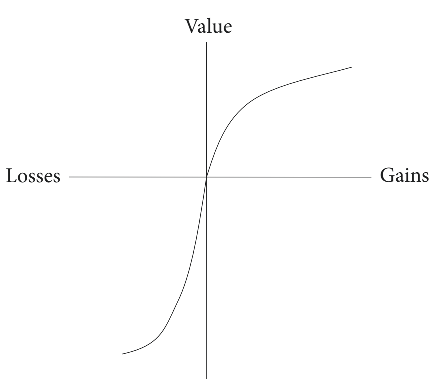

Figure 4: Value function diagram.

they had an average expected return of 5 USD per coin toss (based on expected utility theory). People tend to avoid risk when they are faced with gain and have risk appetites when faced with losses. Kahneman and Tversky found that most people would choose a certain \$800 gain instead of the 85% chance to get \$1000, i.e., risk aversion; at the same time, when the participants face two choices: sure loss of \$800 or 85% probability loss of \$1000, most of the participants chose the latter, namely, risk appetite. Ossenbruggen and Hardman et al. [14] considered that the value function lacks the research logic and belongs to the phenomenological model; Tetlock [15] introduces social and emotional frameworks to the value function; Kahneman et al. [16] integrate Simon's heuristic strategy research results and think that the heuristic strategies people used in decision-making are mainly representative heuristics, easy-to-get heuristics, and anchoring and adjustment heuristics.

4.2.2. Determining the Objective of the Function. In this paper, we address the problem of single-plant site selection. Therefore, the influencing factors mentioned above are set as the main attributes affecting the satisfaction of the enterprise, suppliers, and customers, which is transformed into a multiattribute decision-making problem. We know that the evaluation language is different when evaluating different factors. According to different types of influencing factors, we adopt different methods to quantify the evaluation results. According to the classification of the evaluation results, the attributes of the influential factors affecting the satisfaction can be divided into phrase attributes and clear numerical attributes. For example, regional geographic conditions, regional industrial conditions, regional logistics conditions, service quality, and environmental factors can all be considered phrase-like attributes; construction costs, knowledge costs, and operating costs, as well as transit time, can be categorized as clear numerical attributes. The objective function based on the prospect theory can be expressed as follows.

$$\max V\left(F_{j\gamma}\right) \tag{3}$$

$$\begin{aligned} V\left(F_{j\gamma}\right) = & \sum_{j=1}^{m}\sum_{\gamma=1}^{k} V\left(F_{j\gamma}\right)^{+} w\left(F_{j\gamma}\right) \\ & + \sum_{j=1}^{m}\sum_{\gamma=1}^{k} V\left(F_{j\gamma}\right)^{-} w\left(F_{j\gamma}\right) \end{aligned} \tag{4}$$

4.2.3. Solution Method

Step 1. Assume that the location of suppliers and demand points is known, and select relatively satisfactory candidate

Table 1: Offline channel, attribute evaluation value.

Attributes	Alternatives				
	P1	P2	P3	P4	P5
F1	1575	1294	1159	1234	1468
F2	247	366	401	385	260
F3	117	149	230	166	150
F4	(0,12)	(36,48)	(12,24)	(36,48)	(0,12)
F5	(0,12)	(36,48)	(36,38)	(36,48)	(12,24)
F6	(6/7,1,1)	(3/7,4/7,5/7)	(2/7,3/7,4/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F7	(5/7,6/7,1)	(4/7,5/7,6/7)	(2/7,3/7,4/7)	(2/7,3/7,4/7)	(5/7,6/7,1)
F8	(5/7,6/7,1)	(3/7,4/7,5/7)	(1/7,2/7,3/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F9	(5/7,6/7,1)	(3/7,4/7,5/7)	(2/7,3/7,4/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F10	(5/7,6/7,1)	(4/7,5/7,6/7)	(2/7,3/7,4/7)	(2/7,3/7,4/7)	(5/7,6/7,1)
F11	(3/7,4/7,5/7)	(3/7,4/7,5/7)	(1/7,2/7,3/7)	(3/7,4/7,5/7)	(3/7,4/7,5/7)
F12	(5/7,6/7,1)	(4/7,5/7,6/7)	(3/7,4/7,5/7)	(2/7,3/7,4/7)	(5/7,6/7,1)
F13	(2/7,3/7,4/7)	(3/7,4/7,5/7)	(4/7,5/7,6/7)	(3/7,4/7,5/7)	(3/7,4/7,5/7)

points so that they can better cover the surrounding demand points. According to online channel satisfaction and offline channel satisfaction, each attribute value is calculated for each candidate point, and a program attribute value matrix table is listed, as shown in Table 1.

(a) For numerical attributes, the evaluation result is the actual measured value.

(b) For the language-type attribute, this article uses the commonly used seven-level division method, phrase evaluation grade set $V = \{V_\nu \mid \nu = 1,2,\cdots,7\}$, among which, $V_1 = (\textit{extremely satisfactory})$, $V_2 = (\textit{greater satisfaction})$, $V_3 = (\textit{satisfactory})$, $V_4 = (\textit{neutral})$, $V_5 = (\textit{unsatisfaction})$, $V_6 = (\textit{greater unsatisfaction})$, and $V_7 = (\textit{extremely unsatisfactory})$ scales are used to evaluate the factors that manufacturers use to influence the phrase-type attributes of the candidate sites, through fuzzy trigonometric method to numerical illustration. The evaluation phrase can be converted into a numerical value by a triangular fuzzy formula. The calculation formula is as follows:

$$\widehat{V}_\nu = \left(\max\left\{\frac{\nu-1}{7},0\right\}, \frac{\nu}{7}, \min\left\{\frac{\nu+1}{7},1\right\}\right) \tag{5}$$

where V_ν is the level of the ν-th phrase and $\widehat{V}_\nu$ is the trigonometric fuzzy number of the ν-th phrase level. Then there are

$$\begin{aligned}
\widehat{V}_1 &= \left(0,\frac{1}{7},\frac{2}{7}\right),\\
\widehat{V}_2 &= \left(\frac{1}{7},\frac{2}{7},\frac{3}{7}\right),\\
\widehat{V}_3 &= \left(\frac{2}{7},\frac{3}{7},\frac{4}{7}\right),\\
\widehat{V}_4 &= \left(\frac{3}{7},\frac{4}{7},\frac{5}{7}\right),\\
\widehat{V}_5 &= \left(\frac{4}{7},\frac{5}{7},\frac{6}{7}\right),\\
\widehat{V}_6 &= \left(\frac{5}{7},\frac{6}{7},1\right),\\
\widehat{V}_7 &= \left(\frac{6}{7},1,1\right).
\end{aligned} \tag{6}$$

(c) For interval-type attributes, the attribute value is represented by (a_1,a_2) or $[a_1,a_2]$.

It is assumed that there is an ordered property of fuzzy numbers for each factor [17]. For any $V_\nu \in V, V_{\nu-1} \in V$, if $V_\nu > V_{\nu-1}$, there is $\widehat{V}_\nu \succ V_{\nu-1}$. Among them, "$\succ$" means "*be better than*".

Step 2 (select the reference point for each attribute). The reference point can be set according to the goal of the decision maker, or it can be interpreted as the reference point is the expectation of the decision-makers for each attribute. Therefore, it can be established as

$$\begin{aligned}
\overset{*}{E}_c &= \left(\overset{*}{e}_{c1},\overset{*}{e}_{c2},\cdots,\overset{*}{e}_{cn1}\right),\\
\overset{*}{E}_t &= \left(\overset{*}{e}_{t1},\overset{*}{e}_{t2},\cdots,\overset{*}{e}_{tn1}\right),\\
\overset{*}{E}_a &= \left(\overset{*}{e}_{a1},\overset{*}{e}_{a2},\cdots,\overset{*}{e}_{an1}\right),\\
\overset{*}{E}_q &= \left(\overset{*}{e}_{q1},\overset{*}{e}_{q2},\cdots,\overset{*}{e}_{qn1}\right),\\
\overset{*}{E}_b &= \left(\overset{*}{e}_{b1},\overset{*}{e}_{b2},\cdots,\overset{*}{e}_{bn1}\right),\\
E &= \overset{*}{E}_c \cup \overset{*}{E}_t \cup \overset{*}{E}_a \cup \overset{*}{E}_q \cup \overset{*}{E}_b = \left\{e_\gamma \mid \gamma = 1,2,\cdots,k\right\},
\end{aligned} \tag{7}$$

e_γ is the reference point of the γ-th second-level attributes.

Step 3 (standardized processing). The dimensioning of each attribute value and reference vector is performed. The normalization method is as follows.

Normalize reference point $E = \{e_\gamma \mid \gamma = 1,2,\cdots,k\}$ to $Q = \{q_\gamma \mid \gamma = 1,2,\cdots,k\}$. Set the set of all secondary attribute values to $F' = \{F_{j\gamma} \mid j = 1,2,\cdots,m; \gamma = 1,2,\cdots,k\}$.

Then the normalized set is $V = \{v_{j\gamma} \mid j = 1, 2, \cdots, m; \gamma = 1, 2, \cdots, k\}$. The normalized rules are as follows [18].

(a) For the numeric attributes, the normalized rule is as follows:

normalized reference point as shown in formula (8):

$$q'_\gamma = \begin{cases} \dfrac{\left(e_\gamma - z_1^-\right)}{\left(z_1^+ - z_1^-\right)}, & for\ profit-type\ indexes \\ \dfrac{\left(z_1^+ - e_\gamma\right)}{\left(z_1^+ - z_1^-\right)}, & for\ cost-type\ indexes \end{cases} \tag{8}$$

normalized attributes as shown in formula (9):

$$v'_{j\gamma} = \begin{cases} \dfrac{\left(F_{j\gamma} - z_1^-\right)}{\left(z_1^+ - z_1^-\right)}, & for\ benifit-type\ indexes \\ \dfrac{\left(z_1^+ - F_{j\gamma}\right)}{\left(z_1^+ - z_1^-\right)}, & for\ cost-type\ indexes \end{cases} \tag{9}$$

among which,

$$\begin{aligned} z_1^+ &= \max\left\{\max_{1\le j\le m}\left\{F_{j\gamma}\right\}, e_\gamma\right\} \\ z_1^- &= \min\left\{\min_{1\le j\le m}\left\{F_{j\gamma}\right\}, e_\gamma\right\}. \end{aligned} \tag{10}$$

(b) For the interval-type attributes, the normalized rule is as follows:

normalized reference point as shown in formula (11):

$$\begin{aligned} &\left[q_\gamma^{\prime\prime low}, q_\gamma^{\prime\prime up}\right] \\ &= \begin{cases} \left[\dfrac{\left(e_\gamma^{low} - z_{low}^-\right)}{\left(z_{up}^+ - z_{low}^-\right)}, \dfrac{\left(e_\gamma^{up} - z_{low}^-\right)}{\left(z_{up}^+ - z_{low}^-\right)}\right] & for\ benifit-type\ indexes \\ \left[\dfrac{\left(z_{low}^+ - e_\gamma^{low}\right)}{\left(z_{up}^+ - z_{low}^-\right)}, \dfrac{\left(z_{up}^+ - e_\gamma^{up}\right)}{\left(z_{up}^+ - z_{low}^-\right)}\right] & for\ cost-type\ indexes \end{cases} \end{aligned} \tag{11}$$

normalized attributes as shown in formula (12):

$$\begin{aligned} &\left[v_{j\gamma}^{\prime\prime low}, v_{j\gamma}^{\prime\prime up}\right] \\ &= \begin{cases} \left[\dfrac{\left(v_{jr}^{up} - z_{low}^-\right)}{\left(z_{up}^+ - z_{low}^-\right)}, \dfrac{\left(v_{jr}^{up} - z_{low}^-\right)}{\left(z_{up}^+ - z_{low}^-\right)}\right] & for\ benifit-type\ indexes \\ \left[\dfrac{\left(z_{up}^+ - v_{jr}^{low}\right)}{\left(z_{up}^+ - z_{low}^-\right)}, \dfrac{\left(z_{up}^+ - v_{jr}^{up}\right)}{\left(z_{up}^+ - z_{low}^-\right)}\right] & for\ cost-type\ indexes \end{cases} \end{aligned} \tag{12}$$

among which,

$$\begin{aligned} z_{up}^+ &= \max\left\{\max_{1\le j\le m}\left\{v_{jr}^{up}\right\}, e_\gamma^{up}\right\} \\ z_{low}^- &= \min\left\{\min_{1\le j\le m}\left\{v_{jr}^{low}\right\}, e_\gamma^{low}\right\}. \end{aligned} \tag{13}$$

(c) For the statement-type attributes, the normalized rule is as follows:

normalized reference point as shown in formula (14):

$$q_\gamma''' = \begin{cases} e_\gamma, & for\ benifit-type\ attributes \\ neg\left(e_\gamma\right), & for\ cost-type\ attributes \end{cases} \tag{14}$$

normalized attributes as shown in formula (15):

$$v_{j\gamma}''' = \begin{cases} \widehat{v}_{j\gamma}, & for\ profit-type\ attributes \\ neg\left(\widehat{v}_{j\gamma}\right), & for\ cost-type\ attributes \end{cases} \tag{15}$$

among which, *neg* is an inverse operator.

Step 4. Calculate the distance between each attribute and the reference point.

(a) For numeric-type attributes, distance is calculated according to formula (16).

$$d'_{j\gamma} = \left|v'_{j\gamma} - q'_{j\gamma}\right| \tag{16}$$

(b) For interval-type attributes, distance is calculated according to formula (17).

$$d''_{j\gamma} = \sqrt{\frac{1}{2}\left[\left(v_{j\gamma}^{\prime\prime low} - q_\gamma^{\prime\prime low}\right)^2 + \left(v_{j\gamma}^{\prime\prime up} - q_\gamma^{\prime\prime up}\right)^2\right]} \tag{17}$$

(c) For statement-type attributes, distance is calculated according to formula (18).

$$\begin{aligned} &d_{j\gamma}''' \\ &= \sqrt{\frac{1}{3}\left[\left(v_{j\gamma}^{\prime\prime\prime 1} - q_{j\gamma}^{\prime\prime\prime 1}\right)^2 + \left(v_{j\gamma}^{\prime\prime\prime 2} - q_{j\gamma}^{\prime\prime\prime 2}\right)^2 + \left(v_{j\gamma}^{\prime\prime\prime 3} - q_{j\gamma}^{\prime\prime\prime 3}\right)^2\right]} \end{aligned} \tag{18}$$

Step 5 (calculation of profit and loss value). The profit and loss value indicate that the measurement point is satisfaction and dissatisfaction relative to the reference point. The calculation formula of the values of profit and loss is shown as (19).

$$S\left(F_{j\gamma}\right) = \begin{cases} d_{ij}, & v_{j\gamma} \ge q_\gamma \\ -d_{ij}, & v_{j\gamma} < q_\gamma \end{cases} \tag{19}$$

Among them, when $v_{j\gamma} \ge q_\gamma$, we consider $S(F_{j\gamma})$ to be the satisfaction of attribute value $F_{j\gamma}$ with respect to reference point q_γ; when $v_{j\gamma} < q_\gamma$, we consider $S(F_{j\gamma})$ to be the dissatisfaction of attribute value $F_{j\gamma}$ with respect to reference point q_γ.

Step 6 (calculate the prospect value). According to the prospect theory, the prospect value of attribute $F_{j\gamma}$ is determined by the profit and loss value. The formula is as follows.

$$\begin{aligned} V\left(F_{j\gamma}\right)^+ &= \left(S\left(F_{j\gamma}\right)\right)^\alpha & v_{j\gamma} \ge q_\gamma \\ V\left(F_{j\gamma}\right)^- &= -\theta\left(-S\left(F_{j\gamma}\right)\right)^\beta & v_{j\gamma} < q_\gamma \end{aligned} \tag{20}$$

Among them, α is the degree of concavity of a satisfactory function, and β is the degree of convexity of the dissatisfied function. $\alpha \in (0, 1)$, $\beta \in (1, 0)$ indicate that the sensitivity of

Table 2: Online channel, attribute evaluation values.

Attributes	Alternatives				
	P1	P2	P3	P4	P5
F1	1575	1294	1159	1234	1468
F2	247	366	401	385	260
F3	117	149	230	166	150
F4	(48,60)	(84,96)	(120,132)	(96,108)	(60,72)
F5	(60,72)	(84,96)	(108,120)	(84,96)	(72,84)
F6	(6/7,1,1)	(3/7,4/7,5/7)	(3/7,4/7,5/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F7	(5/7,6/7,1)	(3/7,4/7,5/7)	(1/7,2/7,3/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F8	(5/7,6/7,1)	(3/7,4/7,5/7)	(1/7,2/7,3/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F9	(5/7,6/7,1)	(4/7,5/7,6/7)	(3/7,4/7,5/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F10	(5/7,6/7,1)	(6/7,1,1)	(1/7,2/7,3/7)	(3/7,4/7,5/7)	(2/7,3/7,4/7)
F11	(4/7,5/7,6/7)	(3/7,4/7,5/7)	(1/7,2/7,3/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F12	(5/7,6/7,1)	(3/7,4/7,5/7)	(1/7,2/7,3/7)	(3/7,4/7,5/7)	(5/7,6/7,1)
F13	(4/7,5/7,6/7)	(3/7,4/7,5/7)	(1/7,2/7,3/7)	(3/7,4/7,5/7)	(5/7,6/7,1)

decision-makers to changes in values is diminishing; $\theta > 1$ indicates that the curve of the dissatisfied area is steeper than the curve of the satisfactory area. According to the previous experimental results, we take the value of $\alpha = \beta = 0.88,\ \theta = 2.25$.

Step 7 (calculate comprehensive satisfaction). According to the simple weighting principle, the comprehensive satisfaction degree of each candidate point is calculated according to formula (21).

$$\begin{aligned} V\left(F_{j\gamma}\right) = & \sum_{j=1}^{m}\sum_{\gamma=1}^{k} V\left(F_{j\gamma}\right)^{+} w\left(F_{j\gamma}\right) \\ & + \sum_{j=1}^{m}\sum_{\gamma=1}^{k} V\left(F_{j\gamma}\right)^{-} w\left(F_{j\gamma}\right) \end{aligned} \tag{21}$$

4.2.4. Example Analysis. The decision maker of an equipment manufacturing enterprise A is to establish an independent new plant in the city of U. According to the investigation and survey of the surrounding area of the city, there are five options available for selection. Evaluate and evaluate the attributes of candidate points from both online and offline channels. The weight of each attribute is as follows: because the evaluation results include three different evaluation results: numeric, language, and interval, the results of language evaluation can be converted into triangular fuzzy numbers. The evaluation values are shown in Tables 1 and 2.

According to Steps 1-7, through the calculation steps such as quantifying attribute values, determining expected values, normalizing, calculating profit and loss, etc., the prospect values of each attribute in online and offline channels are calculated, as shown in Tables 3 and 4. The positive and negative values indicate the degree of "better" and "better than", respectively, relative to the ideal point.

Through calculation, the comprehensive prospect values of each candidate point are obtained as below.

$$V\left(F_{j\gamma}\right) = \{0.06, -0.76, -1.57, -1.06, 0.04\} \tag{22}$$

The comprehensive prospect represents the satisfaction of the decision-makers to each scheme. It is known that the decision maker has the highest degree of satisfaction to the alternative point 1 and the priority of the 5 alternatives is 1 to 5.

$$P_1 \succ P_5 \succ P_2 \succ P_4 \succ P_3 \tag{23}$$

With the highest degree of satisfaction as the goal, we should choose 1 plant at the alternative point.

5. The Decision-Making Model of Multiplant Location

5.1. Logical Model. On the basis of the location theory of the maximum coverage, we will explore and study the multiplant location decision problem under the condition of stratified coverage. Based on factors such as the number of demand points and suppliers, the number and location of suppliers, the channels for realizing transactions with upstream and downstream enterprises, and the scale of production of factories, we have established an effective model for practical problems. Among them, the logical model is shown in Figure 5. The establishment of a well-adapted multiplant site selection model can ensure the company's effective interests while fully utilizing the resources' utilization efficiency. It is of great significance to ensure social fairness and promote social development.

5.2. Mathematical Model. The mathematical model was established with the goal of minimum cost and shortest time as follows.

Table 3: Offline channels, property prospect value.

Attributes	Alternatives				
	P1	P2	P3	P4	P5
F1	-1.24	0.21	0.53	0.36	-0.66
F2	0.59	-0.59	-1.11	-0.89	0.51
F3	0.37	0.06	-1.6	-0.32	0.05
F4	0.49	-0.8	0.23	-0.8	0.49
F5	0.54	-0.66	-0.66	-0.66	0.3
F6	0	-0.98	-1.29	-0.98	-0.35
F7	0	-0.4	-1.07	-1.07	0
F8	0	-0.76	-1.37	-0.76	0
F9	0	-0.76	-1.07	-0.76	0
F10	0	-0.4	-1.07	-1.07	0
F11	-0.76	-0.76	-1.37	-0.76	0
F12	0	-0.4	-0.76	-1.07	0
F13	-1.07	-0.76	-0.4	-0.76	0

Table 4: Online channels, property prospect value.

Attributes	Alternatives				
	P1	P2	P3	P4	P5
F1	-1.24	0.21	0.53	0.36	-0.66
F2	0.59	-0.59	-1.11	-0.89	0.51
F3	0.37	0.06	-1.6	-0.32	0.05
F4	0.54	0.12	-0.94	-0.27	0.4
F5	0.57	0.17	-0.73	0.17	-0.35
F6	0	-0.98	-0.98	-0.98	-0.35
F7	0	-0.76	-1.37	-0.76	0
F8	0	-0.76	-1.37	-0.76	0
F9	0	-0.4	-0.76	-0.76	0
F10	-0.35	0	-1.58	-0.98	-1.29
F11	-0.4	-0.76	-1.37	-0.76	0
F12	0	-0.76	-1.37	-0.76	0
F13	-0.4	-0.76	-1.37	-0.76	0

$$\min \quad C = C_{Tr} + C_{Rt} + C_{\mathrm{Pr}} \tag{24}$$

$$C_{Tr} = C_{Tr}^{off} + C_{Tr}^{on} \quad \begin{cases} C_{Tr}^{off} = \sum_{i=1}^{l}\sum_{j=1}^{m} w_1^{off} d_{ij} Q_{ij} x_j a_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{n} w_2^{off} d_{jk} Q_{jk} x_j a_{ij} \\ C_{Tr}^{on} = \sum_{i=1}^{l}\sum_{j=1}^{m} w_1^{on} d_{ij} Q_{ij} x_j b_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{n} w_2^{on} d_{jk} Q_{jk} x_j b_{ij} \end{cases} \tag{25}$$

$$C_{Rt} = C_{Rt}^{off} + C_{Rt}^{on} \quad \begin{cases} C_{Rt}^{off} = \sum_{i=1}^{l}\sum_{j=1}^{m} y_1^{off} \zeta_1^{off} Q_{ij} x_j a_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{n} y_2^{off} \zeta_2^{off} Q_{jk} x_j a_{ij} \\ C_{Rt}^{on} = \sum_{i=1}^{l}\sum_{j=1}^{m} y_1^{on} \zeta_1^{on} Q_{ij} x_j b_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{n} y_2^{on} \zeta_2^{on} Q_{jk} x_j b_{ij} \end{cases} \tag{26}$$

$$C_{\mathrm{Pr}} = C_f + C_v \cdot Q \quad C_{\mathrm{Pr}} = \sum_{j=1}^{m} C_f^j x_j + \sum_{j=1}^{m} C_v^j Q_j x_j \tag{27}$$

$$\min \quad T = T_{Tr} + T_{Rt} \tag{28}$$

$$T_{Tr} = T_{Tr}^{off} + T_{Tr}^{on} \quad \begin{cases} T_{Tr}^{off} = \sum_{i=1}^{l}\sum_{j=1}^{m} \tau_1^{off} d_{ij}\varphi_{ij}x_j a_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{n} \tau_2^{off} d_{jk}\varphi_{jk}x_j a_{ij} \\ T_{Tr}^{on} = \sum_{i=1}^{l}\sum_{j=1}^{m} \tau_1^{on} d_{ij}\varphi_{ij}x_j b_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{n} \tau_2^{on} d_{jk}\varphi_{jk}x_j b_{ij} \end{cases} \tag{29}$$

$$T_{Rt} = T_{Rt}^{off} + T_{Rt}^{on} \quad \begin{cases} T_{Tr}^{off} = \sum_{i=1}^{l}\sum_{j=1}^{m} \tau_1^{off} d_{ij}\varphi_{ij}y_1^{off} x_j a_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{n} \tau_2^{off} d_{jk}\varphi_{jk}y_2^{off} x_j a_{ij} \\ T_{Rt}^{on} = \sum_{i=1}^{l}\sum_{j=1}^{m} \tau_1^{on} d_{ij}\varphi_{ij}y_1^{on} x_j b_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{n} \tau_2^{on} d_{jk}\varphi_{jk}y_2^{on} x_j b_{ij} \end{cases} \tag{30}$$

$$\text{Subject to:} \quad 0 \le D_j^1 \le D_j^2 \tag{31}$$

$$\sum_j x_j \le z \tag{32}$$

$$Q_{ij} = q\varphi \tag{33}$$

$$\sum_j Cf_j \le F \tag{34}$$

$$a_{ij} \le x_j \tag{35}$$

$$b_{ij} \le x_j \tag{36}$$

$$\sum Q_{ij} \le \Omega \tag{37}$$

$$\sum Q_{jk} \le \mho \tag{38}$$

$$\zeta_2^{off}, \zeta_2^{on} \le C_v \tag{39}$$

$$Q_j x_j \ge m_j \tag{40}$$

$$x_j \in \{0, 1\} \tag{41}$$

$$a_{ij} \in \{0, 1\} \tag{42}$$

$$b_{ij} \in \{0, 1\} \tag{43}$$

Among them, (24) represents the lowest cost target, and the specific target comprises three parts: raw material transportation cost, product transportation cost, and product production cost; (25) is the offline raw material transportation cost and online raw material transportation cost; (26) indicates the cost of transportation under the product line and the cost of online transportation; (27) represents the production cost of the product, including fixed costs and total variable costs; (28) represents the minimum time target and specific time objectives, including transportation time and return time; (29) means transport time, including raw material transport time and product transport time, online raw material transport time, and product transport time; (30) represents return time, including offline raw material return time and product return time, online raw material return time, and product return time; (31) indicates that the offline transport distance is less than the online transport distance and is greater than zero (because it is a ring load cover); (32) represents the number of built factories; (33) means that the total amount of transport is equal to the amount of transport multiplied by the number of shipments; (34) means total fixed cost constraint; (35) means that the plant can be purchased; (36) means that the plant can be sold; (37) means that the raw material resources are constrained; (38) means that the market capacity is limited; (39) means that the offline and online return costs are less than the variable cost. If the return cost is greater than the variable production cost, no return is required. (40) indicates that the production capacity is greater than a certain capacity. (41), (42), and (43) represent the range of values for the decision variable.

5.3. Algorithm Design. For solving coverage problems, we use genetic algorithms to get a feasible solution with high satisfaction. Genetic algorithm as a classical algorithm is an open source for researchers, which is a computational model that simulates the natural evolution of biological evolution theory and the processes of genetic mechanism. The specific steps are as follows.

Step 1 (coding). Binary coding is the most commonly used coding method in genetic algorithms. It includes advantages of (a) being simple and easy, (b) conforming to the minimum character set coding principle, and (c) being convenient for analyzing with the pattern theorem. If interval $[a, b]$ is a domain and δ is the required precision, we can assume that the length of the chromosome is l, shown as follows.

$$l = \log \frac{b-a}{\delta} + 1 \tag{44}$$

Step 2 (generating the initial population). A subset of individuals (the same individual can exist) is generated by random numbers, called population P_0.The size of the population is measured by N. We assume that the first generation subset data is the initial value and starts iterating. Under the premise of ensuring the diversity of the solution, in order to improve the speed of convergence and get a satisfactory solution as soon as possible, we let the population size be $N = 100$. The language of MATLAB is $popsize = 100$.

Step 3 (definition of fitness function). We use boundary structure method to construct fitness function in this model. If the function value is as big as possible, then

$$Fit\left(f\left(X\right)\right) = \begin{cases} c_{\max} - f\left(x\right), & f\left(x\right) < c_{\max} \\ 0, & others. \end{cases} \tag{45}$$

And if the function value is as small as possible, then

$$Fit\left(f\left(X\right)\right) = \begin{cases} f\left(x\right) - c_{\min}, & f\left(x\right) > c_{\min} \\ 0, & others. \end{cases} \tag{46}$$

Among them, $c_{\max}$ is the maximum estimate of $f(x)$, and $c_{\min}$ is the minimum estimate of $f(x)$.

Step 4 (generate newborn populations). Crossover and mutation operations and determination of operating parameters: This step mainly selects cross-mutation activities between chromosomes with better fitness values. Its purpose is to get the chromosomes with higher fitness values. At the same time it determines the relevant operating parameters, such as crossover rate, mutation rate, and population size. In this paper, in order to fully cross each generation, we select $pc = 0.8$ (generally 0.6-1.0) as crossover rate and $pm = 0.01$ (generally 0.01-0.1) as mutation rate.

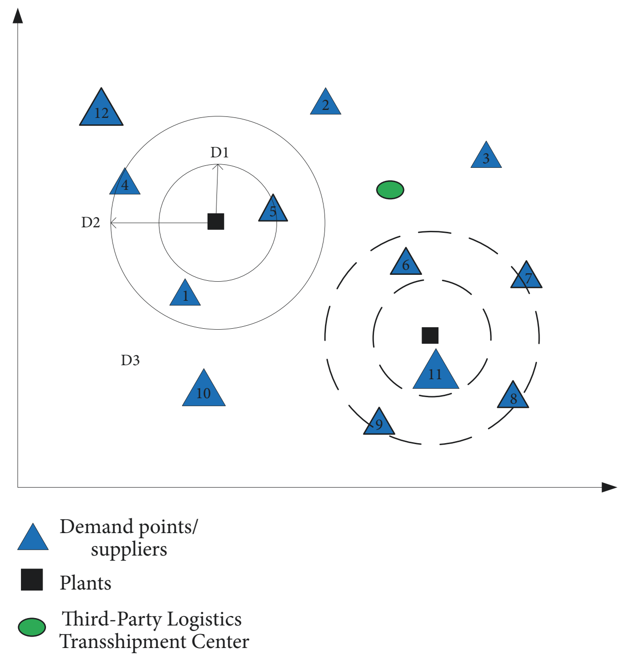

Figure 5: Logical model of multiplant location.

Step 5 (matching facilities and demand points). (1) from the view of plant Q_{ij}, Q_{jk}, d_{ij}, and d_{jk}, effective facility allocation ensures that facilities are built to the maximum demand point coverage.

(2) Determine whether the demand covered by the same factory is greater than the factory's maximum production capacity. If not, then continue to run $i + 1$; if yes, return (1) to redistribute.

Evaluate whether the demand covered by a plant exceeds the maximum capacity of the plant. If not, iterative procedure continues to run $i + 1$; if yes, return (1) to redistribute.

Step 6. Based on the allocation scheme in step 5, the target value of the initial population can be found.

Step 7 (recalculate the target value). On the basis of the parameters in step 6, the single-point crossover, and single-point mutation on the chromosome, with high fitness in the initial population, regeneration of the N chromosome, and formation of a new population P_1, we can get the new target value.

Step 8 (optimal selection). Combining the initial population P_0 and the newest species group P_1, the newest population of the better N chromosome is still selected to form a new population P_2 according to the target value. After the crossover and variation of N times, a satisfactory solution was selected.

5.4. Example Analysis. SY City is an important central city, advanced equipment manufacturing base, and national historical and cultural city of the provincial capital, sub-provincial city, and megacities approved by the State Council and approved by the State Council. The city administers 10

Table 5: Coordinates and quantity of suppliers for raw materials.

No	Coordinates	Supply quantity	No	Coordinates	Supply quantity	No	Coordinates	Supply quantity
1	58,2	741	18	39,42	705	35	3,92	448
2	29,91	656	19	20,92	657	36	33,73	682
3	83,80	632	20	84,16	322	37	42,51	479
4	20,78	543	21	50,67	372	38	15,15	331
5	21,70	619	22	1,42	394	39	84,55	534
6	71,37	330	23	43,69	371	40	37,97	341
7	41,11	494	24	10,82	576	41	87,4	371
8	6,1	676	25	62,98	764	42	14,50	503
9	55,59	392	26	18,55	787	43	52,78	494
10	22,14	405	27	7,34	610	44	97,63	557
11	26,52	479	28	38,46	631	45	35,21	723
12	9,5	518	29	9,98	576	46	93,15	462
13	10,10	504	30	88,57	671	47	15,52	723
14	96,48	541	31	41,97	459	48	90,44	749
15	20,82	433	32	65,3	564	49	59,63	752
16	3,22	797	33	70,53	537	50	7,25	611
17	56,85	655	34	89,10	468			

districts, 2 counties, and 1 county level. The city has an area of 12,900 square kilometers, resident population of 8,291,000, and urbanization rate of 80.55%. At present, a 10 × 10 area Sino-German manufacturing industry park is planned to be calculated, and 50 supply points are provided. The specific coordinates and supply quantities are shown in Table 5. The demand points are 100, and the specific coordinates and demand are shown in Table 6. At present, after the analysis of the basic conditions, there are 25 locations where the proposed site can be constructed. The specific coordinates and output are shown in Table 7.

The values of other parameters are shown as follows.

$$\begin{aligned} w_1^{off} &= 1.5, \\ w_2^{off} &= 1.8, \\ w_1^{on} &= 3.0, \\ w_2^{on} &= 3.5 \\ y_1^{off} &= 1\%, \\ y_2^{off} &= 2\%, \\ y_1^{on} &= 4\%, \\ y_2^{on} &= 5\% \\ \tau_1^{off} &= 3\text{d}, \\ \tau_2^{off} &= 4\text{d}, \\ \tau_1^{on} &= 7\text{d}, \\ \tau_2^{on} &= 8\text{d} \\ \left[D_j^1, D_j^2\right] &= [1, 3] \end{aligned} \tag{47}$$

Then, we have the following.

$$\begin{aligned} R_1 &= 1, \\ R_2 &= 3 \\ \max z &= 20 \end{aligned} \tag{48}$$

There are three types of cars, the volume of transportation is as follows.

$$\begin{aligned} q_1 &= 100, \\ q_2 &= 200, \\ q_3 &= 300 \\ C_f &= 100000 \\ C_v &= 5 \\ \zeta_2^{off} &= 1.2, \\ \zeta_2^{on} &= 1.5 \\ \sum Q_{ij} &\leq 10000 \\ \sum Q_{jk} &\leq 15000 \end{aligned} \tag{49}$$

The parameters of the genetic algorithm are set: the population size is 100, the crossover rate is 0.8, the variation rate is 0.01, and the iteration number is 200. As shown in Figure 6

From Figure 6, as the number of iterations increases, the first target value with the minimum cost as the target is gradually reduced, while the second target value with the minimum time as the target is gradually increased, and the two targets constrain each other, so the target values are back against the law. When the number of iterations is 131

Table 6: Coordinates and demand quantity of demand point.

No	Coordinates	Demand quantity	No	Coordinates	Demand quantity	No	Coordinates	Demand quantity
1	99,23	489	35	62,68	468	68	38,44	430
2	23,50	942	36	65,98	747	69	58,21	799
3	24,83	447	37	5,95	472	70	96,47	593
4	2,76	565	38	42,84	699	71	99,25	841
5	47,99	902	39	88,41	797	72	24,25	854
6	62,99	714	40	93,9	782	73	5,63	710
7	52,29	833	41	96,82	894	74	3,85	405
8	27,25	690	42	35,75	534	75	25,25	559
9	56,8	486	43	68,96	465	76	35,73	901
10	14,24	732	44	3,27	450	77	88,99	608
11	54,82	946	45	77,52	775	78	73,44	782
12	37,10	475	46	1,78	568	79	96,23	614
13	11,59	810	47	48,10	892	80	56,63	843
14	23,16	643	48	32,90	755	81	85,22	618
15	5,95	477	49	65,17	413	82	39,87	736
16	66,24	953	50	21,73	769	83	15,62	625
17	40,61	736	51	76,11	561	84	2,5	604
18	32,26	704	52	47,68	706	85	1,58	424
19	67,12	414	53	32,69	724	86	48,17	910
20	15,38	518	54	92,7	840	87	20,38	979
21	80,100	791	55	24,4	825	88	76,33	789
22	25,36	468	56	61,25	740	89	57,44	614
23	93,86	927	57	34,0	746	90	69,32	582
24	4,98	756	58	14,50	780	91	56,85	787
25	95,94	482	59	86,46	585	92	64,47	648
26	75,35	839	60	76,19	726	93	96,8	692
27	35,35	560	61	38,82	825	94	29,66	418
28	71,54	797	62	37,20	759	95	77,50	794
29	1,2	535	63	82,52	680	96	73,17	600
30	26,46	478	64	47,14	537	97	31,80	970
31	30,52	691	65	53,11	593	98	92,15	906
32	94,4	888	66	40,55	790	99	68,56	473
33	91,53	849	67	42,36	856	100	52,69	856
34	98,63	663						

Table 7: Coordinates and quantity of plants.

No	Coordinates	Output	No	Coordinates	Output	No	Coordinates	Output
1	48 23	2620	9	41 90	3730	17	80 46	2910
2	6 95	3770	10	77 62	2810	18	14 13	3280
3	98 31	2780	11	36 66	3430	19	85 17	3960
4	28 79	3170	12	63 38	2870	20	24 3	2790
5	75 51	3620	13	72 58	3310	21	69 42	3200
6	92 47	2650	14	86 73	2590	22	91 64	2950
7	78 87	2760	15	43 34	2560	23	35 52	3800
8	40 89	2900	16	37 57	3380	24	5 97	2550
						25	21 25	3840

Table 8: Approximate to the target value of the Pareto optimal solution.

Scheme	Numbers of plants	Total cost	Total time
1	11	1617.91	333.75
2	11	1628.62	329.74
3	12	1638.01	324.54

Table 9: The relationship between location and demand distribution of scheme 1.

	Scheme 1	
No	Alternative points	Demand and supply points
1	10	3, 30, 47, 98, 51, 2, 78, 5
2	14	35, 55, 99, 1, 7, 48, 12, 100
3	20	63, 58, 19, 69, 84, 16, 80
4	7	74, 62, 95, 65, 60
5	22	15, 29, 10, 33, 14, 90, 59, 8
6	11	24, 64, 52, 36, 73, 4
7	4	50, 34, 43, 18, 11, 83, 39
8	23	97, 53, 57, 28, 54, 87, 72
9	17	9, 6, 26, 92, 86, 44, 81, 17
10	6	25, 77, 88, 46, 38, 42, 49, 85
11	2	67, 91, 20, 45, 79, 94, 75

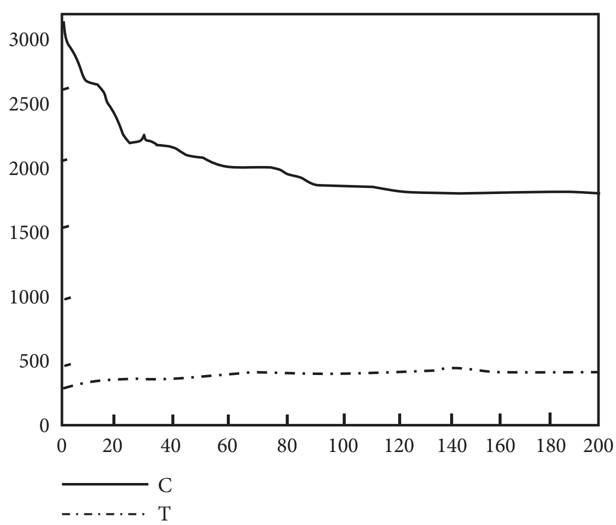

Figure 6: The relationship between the number of iterations and the value of the objective function.

generations, the two target values are convergent. It can be seen that the genetic algorithm adopted in this section has good convergence for solving this model. Thus, the most suitable location and allocation of multiple plants can be determined. 3 approximate Pareto optimal solutions are randomly selected from the optimization front, and the plant number and target value are shown in Table 8.

In this case, we can know from the calculation results that the optimal number of plants to be built is 11 or 12 plants. Due to the different construction plans, the construction costs and transportation time will be different. There are three situations. In the first, the system cost is the smallest, and the system will spend more time to deal with the demand. In the second, the system cost is the largest, but the system will spend less time to deal with business processes such as purchase, sale, and return. The third situation is between the above two situations. Therefore, when choosing a plan, the decision-makers should consider the two objectives comprehensively, not only pay attention to the minimum cost or the shortest time. According to the actual conditions, including the external environmental factors and policy conditions of the enterprises, we make targeted decisions. In this case, we have chosen the second scheme in consideration of the dual-channel marketing model, the surrounding industrial conditions of the alternative sites, and the local government's regional policies for the industry. The distribution of alternative points and demand points is shown in Tables 9–11.

6. Discussion

In this paper, we have a positive guiding significance for the site selection of manufacturing enterprises in the e-commerce environment. At the same time, due to constraints of energy, ability, and time, this paper has some limitations. For example, the main influencing factors and evaluation indicators identified in this paper come from the authors' team's consensus on past research and actual investigations of some enterprises. Due to the limitations of the regional sample, the determination of the influencing factors and the weights will be biased. Therefore, interested readers can further explore such site selection issues. In particular, in the model of multiplant location, we only consider two objectives of cost and time. But in the practical problems, the location of the enterprise usually has more objective constraints, such as service quality, service efficiency, production scale, production flexibility, and green environmental

Table 10: The relationship between location and demand distribution of scheme 2.

	Scheme 2	
No	Alternative points	Demand and supply points
1	8	25,92,96,68,55,4,23
2	3	60,45,10,28,87
3	12	51,52,30,54,18,66,9
4	25	17,13,88,37
5	15	15,50,3,47,11,29,26,85
6	17	89,76,58,24,94,81
7	9	74,90,35,71,48,16,98,31,78
8	16	97,53,31,61,70,62,93
9	21	39,72,86,46,27,7,5,19,12,84
10	14	32,59,22,21,44,36,38,67,8
11	18	69,65,20,41,57,73,2,49

Table 11: The relationship between location and demand distribution of scheme 3.

	Scheme 3	
No	Alternative points	Demand and supply points
1	5	32,50,72,55,38,62
2	24	71,51,53,97,3,66,74,96,89
3	17	34,20,94,80,76,2
4	20	58,56,30,100,60,26,54
5	11	52,25,10,85,84,7,28,86
6	12	92,19,37,75,4,82,42,79,87
7	8	14,95,65,99,6,31,93,16,46
8	4	70,1,73,44,27,35,33
9	23	43,48,98,49,5,45,40
10	19	21,69,36,77,83,91,18
11	16	81,15,64,9,22,11,47
12	18	61,63,24,23,67,59

protection. Secondly, we do not consider the relationship between transport rates, unit distance, and transportation time. In the process of analyzing the example, many variables are changed into parameters in order to avoid heavy and complex calculation process. The location problem is the NP-hard problem, and it cannot find the optimal solution in the process of solving the problem, so the results provided in this paper are only a relatively satisfactory result. We hope that in the future research and work, we will have the opportunity to continue the discussion, and we also hope that more scholars who work on the location problem can continue excavating such problems.

7. Conclusion

Based on the research of location theory and classical location problems, combined with the current status of dual-channel purchase and sales of current equipment manufacturing enterprises, we propose the problem of single-plant and multiplant location under dual-channel purchase and sale model. Through the verification and analysis of the examples, we draw the following conclusions: (1) Equipment manufacturing enterprises with a dual-channel marketing model are a major feature of current industrial transformation and industrial revolution and are also the current trend of industrial manufacturing plants. (2) Relative to the traditional plant site selection decisions, with the dual-channel procurement and sales model, the location of the equipment manufacturing company's factories is more focused on the degree of intelligence around the candidate sites and the development status of the surrounding industries. (3) The construction cost and operating cost are the main factors that need to be considered in the process of site selection. We cannot blindly pursue cost savings, but also pay attention to the development opportunities of enterprises, supporting the development of upstream and downstream enterprises.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors of this study state that there are no conflicts of interest to disclose.

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